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Editorial

Editorial for the Special Issue "Diversity, Ecology and Evolution of Odonata"

M. Olalla Lorenzo-Carballa [1,*] and Ricardo Koroiva [2]

1 CRETUS, Department of Zoology, Genetics and Physical Anthropology, Universidade de Santiago de Compostela, 15782 Santiago de Compostela, Spain
2 Biological Science Institute, Federal University of Pará, Belém 66075-110, Pará, Brazil; ricardo.koroiva@gmail.com
* Correspondence: m.o.lorenzo.carballa@gmail.com

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1. Introduction

The Odonata is an order of insects commonly known as dragonflies and damselflies, with a worldwide distribution except in Antarctica. The group includes more than 6300 species, which are divided into three suborders (Figure 1) [1]: the Zygoptera (damselflies), which have a slender body and hold their wings closed over the back when at rest; the Anisoptera (dragonflies), which have a thicker body and hold their wings perpendicular to the body when at rest; and the Anisozygoptera, a smaller suborder that includes four species that have intermediate characteristics between dragonflies and damselflies.

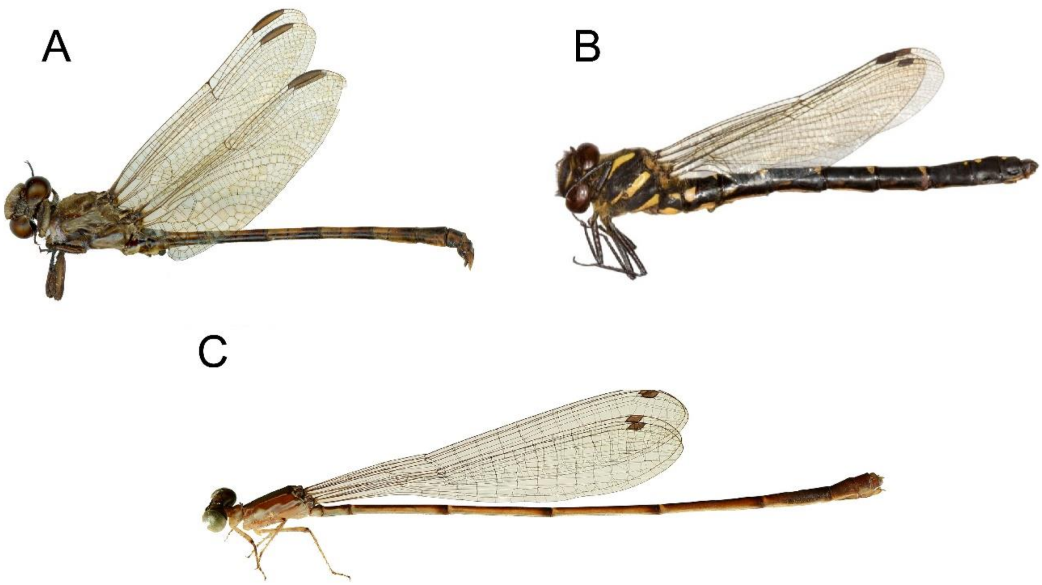

Figure 1. Specimens from three suborders: (**A**) Anisoptera, (**B**) Anisozygoptera, and (**C**) Zygoptera. Reproduced with permission from Adolfo Cordero-Rivera and Diogo Silva Vilela.

Members of the order Odonata play an important ecological role as predators (see [2]). They consume large volumes of prey such as mosquitoes, flies, and other small insects, thus contributing to the regulation of insect populations; they also constitute important prey for larger animals such as birds, fish, and amphibians. In addition, Odonata occupy an important evolutionary position, being one of the oldest groups of flying insects, with fossils dating back more than 300 million years [3]. Due to their sensitivity to environmental changes, Odonata are used as bioindicators for freshwater quality assessment, wetland protection monitoring, and environmental impact assessment. Finally, the beauty and diversity of Odonata species also make them attractive to the general public, which has led to an increased interest in both their natural history and conservation [4].

In this Special Issue of *Diversity*, we invited fellow odonatologists to share their research findings on some of the most important topics related to the knowledge of this insect order: Diversity, Ecology, and Evolution. The twenty-one articles published in this issue address all of these topics to some extent.

2. Diversity

This section of the Special Issue opens with the article "Diversity of Palaearctic Dragonflies and Damselflies (Odonata)" [5], in which the authors present the results of a study in which they created distribution models for 402 dragonfly and damselfly species in the Palaearctic region, the largest biogeographical realm area, using more than 1.2 million distribution data. The study revealed a clear pattern of longitudinally declining diversity, with lentic species dominating in colder and drier areas. The article highlights the importance of understanding diversity patterns and threats to dragonflies in the Palearctic region for the conservation of these important insect species.

The second article, "Diversity of Nearctic Dragonflies and Damselflies (Odonata)" [6], presents a study on the diversity of dragonflies and damselflies in the Nearctic, a biogeographic region that includes Canada, the United States, and Mexico. The study used species distribution modeling and found greater species richness in the eastern part of the region and high levels of endemism in the southeastern United States, likely due to glacial refugia. The study emphasizes the importance of understanding the aquatic life cycle and requirements of dragonflies and damselflies to understand the distribution patterns of their diversity in the Nearctic.

The article "Taxonomic revision of eastern part of Western Palaearctic *Cordulegaster* using molecular phylogeny and morphology, with the description of two new species (Odonata: Anisoptera: Cordulegastridae)" [7] combines molecular and morphological techniques to clarify the taxonomy of the genus *Cordulegaster* Leach in Brewster, 1815. This study confirms the existence of the two traditional groups (*boltonii* and *bidentata*) and describes little-known or new taxa with their phenotypic variation. The molecular analyses support three known and one new species in the *boltonii* group, and a complex of four closely related species in the *bidentata* group, with one additional new species described for this group. The study also provides an identification key for all western Palaearctic *Cordulegaster*. Its importance for dragonfly research lies in its contribution to the taxonomic knowledge of this genus in the Eastern part of the Western Palaearctic region.

The article "Molecular and morphological analyses support different taxonomic units for Asian and Australo-Pacific forms of *Ischnura aurora* (Odonata, Coenagrionidae)" [8] presents the results of a study on the taxonomic status of *Ischnura aurora* (Brauer, 1865), a dragonfly species that has been the subject of taxonomic debate for many years. Using morphological and DNA sequencing analyses, this study concludes that the Australo-Pacific and Asian forms of *I. aurora* should be separated into two distinct species: *I. aurora* and *I. rubilio*, respectively. Furthermore, the study highlights the need to review all available material of the different subspecies of *I. aurora* and emphasizes the importance of the careful examination of DNA sequence data and voucher specimens in taxonomic studies to avoid specimen misidentifications and/or the amplification of non-orthologous copies of mitochondrial gene markers.

Finally, the article "DNA barcoding and new records of odonates (Insecta: Odonata) from Paraíba state, Brazil" [9] reports the results of a study of Odonata species in the Brazilian state of Paraíba and the creation of a DNA barcoding database for 70% of the species found in this state. The results show that the use of the COI fragment at the regional level can help in the identification and delimitation of species, and that morphological characteristics can be used to further confirm such identifications. The establishment of this DNA barcode library is an important milestone for the taxonomy and conservation of the biodiversity of Neotropical odonate species.

3. Ecology

The Ecology section opens with the article "Climate change is driving shifts in dragonfly species richness across Europe via differential dynamics of taxonomic and biogeographic groups" [10], which discusses the importance for conservation of understanding how changes in species richness correlate with changes in the range of different taxonomic and biogeographic groups. This study found that large-scale changes in dragonfly species richness are the result of several divergent dynamics that differ for taxonomic suborders and biogeographic groups, with thermal releases during climate-driven range expansion shifting local species richness across Europe. Dragonflies are proving to be important indicators of environmental status and conservation needs, highlighting the relevance of the topic to the Odonata field.

The article "Niche breadth predicts geographical range size and northern range shift in European dragonfly species (Odonata)" [11] discusses the relationship between niche breadth, range size, and range shifts in European dragonflies over a 22-year period. The study found that stream species with narrower niches and smaller ranges are more vulnerable to habitat loss and climate change, while species living in temporary water bodies are more resilient to climate change than species living in permanent water bodies. The results suggest that ongoing climate change and changes in land use will mostly affect species with narrow habitat requirements, leading to biotic homogenization in which specialists are displaced and replaced by generalists. The results of the study have important implications for understanding the effects of climate change and land use on dragonfly populations and can be used to better inform conservation measures.

"Similar response of a range expanding dragonfly to low- and high-elevation predators" [12] describes a common garden experiment with the dragonfly species *Sympetrum striolatum* to test whether they can cope with new biotic interactions in expanding ranges. The study found that the dragonflies responded similarly to low- and high-elevation predators in terms of growth and feeding, but they responded more significantly to the familiar predator in terms of morphology. These results suggest that species that expand their range can successfully colonize new areas at higher elevations because they respond similarly to dominant predators at high elevations as they do to familiar predators at low elevations.

The study "First record of microsporidia infection in the damselfly *Ischnura elegans* larvae: temperature and predator cue effects on the host's life history" [13] reports on the first microsporidia infection in laboratory-reared damselfly *Ischnura elegans* larvae from adult females collected in the field in Poland. The study found that higher rearing temperatures and predation cues from alien signal crayfish increased the number of infected larvae, leading to distorted wing development and death before hatching. The results suggest that ecologically challenging conditions can increase the risk of parasitism and emphasize the importance of considering the effects of microsporidian infection on dragonflies, which are often used as model organisms in eco-evolutionary studies.

The article "Evaluating potential distribution and niche divergence among populations of the world's largest living damselfly, *Megaloprepus caerulatus* (Drury, 1782)" [14] reports on a study of ecological divergence between populations of *Megaloprepus caerulatus* in Mexico, Costa Rica, and Panama. The authors used Ecological Niche Modeling (ENM) to compare potential distribution ranges and found evidence of strong ecological divergence between the Corcovado and Barro Colorado populations. The study lays the stage for further research on the factors driving niche divergence, and the effects of anthropogenic land use change and climate change on the distribution and conservation of this emblematic Neotropical species.

Two articles in this section dealt with land use for pasture and cocoa cultivation in the Brazilian state of Bahia. The first one, entitled "Land uses for pasture and cacao cultivation modify the Odonata assemblages in Atlantic Forest areas" [15], investigates the effects of changes in land use on Odonata assemblages in the Atlantic Forest of Brazil. The study found that changes such the conversion of original forest areas to pasture significantly alter the richness and composition of Odonata assemblages. The study shows the importance of conserving riparian vegetation and implementing sustainable land use practices to protect aquatic ecosystems and biodiversity. The second article, "Dragonflies (Odonata) in cocoa growing areas in the Atlantic Forest: taxonomic diversity and relationships with environmental and spatial variables" [16], investigated the impact of cocoa cultivation on Odonata assemblages and determined the relationship between different life stages of Odonata and local and spatial environmental variables. The study found that agroforestry cabruca areas where cocoa is grown in the shade of native trees harbor a variety of dragonfly species, including forest specialists, and that local and spatial environmental characteristics are important factors in structuring these assemblages. The results emphasize the importance of this agroforestry system for the conservation of dragonfly species in areas of the Atlantic Forest.

In "Odonata from Iberá wetland system (Corrientes, Argentina), are regional biogeographic schemes useful to assess Odonata biodiversity and its conservation?" [17], the authors analyzed the distribution patterns of Odonata species in the wetlands of the Iberá depression in Argentina to determine whether this region functions as an ecological and functional unit. They found that the Iberá Depression is not a functional unit and that Odonata respond to specific physical features of the wetlands rather than to biogeographical or ecoregional schemes. This study is important for dragonfly research because it emphasizes the need to understand the specific environmental factors that influence their distribution and the importance of local conservation measures for these species.

4. Evolution

The section on Evolution opens with the article "Genetic diversity and structure of *Anax imperator* Leach, 1815 populations (Odonata: Aeshnidae) in ponds at regional and European scales" [18], which examines the genetic diversity and structure of *Anax imperator* populations in Europe using microsatellite markers. The study found high gene flow at both regional and European scales and no pattern of isolation by distance, indicating historical or recent movements of individuals. The results highlight the potential role of the English Channel as a barrier to gene flow and the need for further studies to investigate the relationship between individuals and major wind currents. Overall, the study provides insights into the gene flow and dispersal patterns of *A. imperator* that may aid in the conservation of the species and the management of fragmented habitats.

The article "Evolution and biogeographic history of rubyspot damselflies (Hetaerininae: Calopterygidae: Odonata)" [19] presents the results of a study on the biogeography, ecology, and color evolution of Neotropical Hetaerininae damselflies. The study concludes that the genus *Hetaerina* is paraphyletic and that a reclassification of the genera within the Hetaerininae is needed. The study also provides evidence for a gradual dispersal of the Hetaerininae from North to South America that began in the Oligocene and ended in the Pliocene, and suggests that the expansion of the Isthmus of Panama during the Oligocene contributed to their dispersal. The relevance of the topic lies in its contribution to our understanding of the relationship between morphology, biogeography, and habitat in a charismatic group of damselflies.

The study "Testing the effect of Sampling effort on inferring phylogeographic history in *Psolodesmus mandarinus* (Calopterygidae, Odonata)" [20] discusses the effect of sampling design on phylogeographic inference and its implications for the study of spatial genetic structure and evolutionary units. The authors demonstrate the importance of a comprehensive sampling design for understanding the phylogeographic history of a dwarf dragonfly endemic to Taiwan, *Psolodesmus mandarinus*, and point out the potential bias in inferring the effects of isolation by a physical barrier. The study highlights the need to use careful spatial sampling strategies in future phylogeographic studies and to test the effects of sampling on the resulting inferences, which is crucial for progress in the field of dragonfly genetics and evolution.

The article "The quality of sequence data affects biodiversity and conservation perspectives in the Neotropical Damselfly *Megaloprepus caerulatus*" [21] discusses the importance of high-quality raw sequence data for species delimitation and discovery in odonate research, using the Neotropical damselfly genus *Megaloprepus* as an example. The study compares two sets of sequence markers used in previous research and identifies unresolved features and internal gaps as reasons for the different results in species delimitation and population genetic relationships. The article emphasizes the importance of accurate species delimitation for conservation management, especially for sensitive species such as those within the genus *Megaloprepus*.

In "Meiotic analysis of Gomphidae species sheds light on the large X chromosome of the family (Anisoptera, Odonata)" [22], a hypothesis about the original diploid number and sex-determining systems in the dragonfly family Gomphidae is proposed. The study analyzes the meiosis and heterochromatin characteristics of three species of Gomphidae from Argentina and suggests that the diploid number of the family was 23 and the large size of the sex chromosome is due to an increase in heterochromatin rather than structural rearrangements. The results of the study and the proposed hypothesis offer new insights into the evolutionary history and sex-determining mechanisms in Odonata.

5. Review Article

The Special Issue closes with a bibliometric analysis of Odonata research at a global scale, entitled: "A bibliometric analysis of the global research in Odonata: trends and gaps" [23]. The authors present the results of a study on the patterns of research on dragonflies and damselflies over the last ten years based on a bibliometric analysis of publications. They show that the number of publications on Odonata has increased, with ecology, taxonomy, and behavior being the main topics of the studies published in this time period. However, there are still some research gaps, especially in basic biology, biogeography, and knowledge about the larval stage of Odonata. This review also highlights the importance of increasing research efforts in neglected areas to better understand species' responses to various factors and to expand the necessary background information for other types of studies.

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